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(54) **WINDSHIELD AREA INTRUSION CONTROL**

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B60R 21/205 (2011.01)
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CPC **B60R 21/205** (2013.01); **B32B 17/064** (2013.01); **B60J 1/02** (2013.01);
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CPC B62D 25/082; B62D 25/081; B60R 2021/343; B60R 2021/0004;
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Primary Examiner — Paul N Dickson

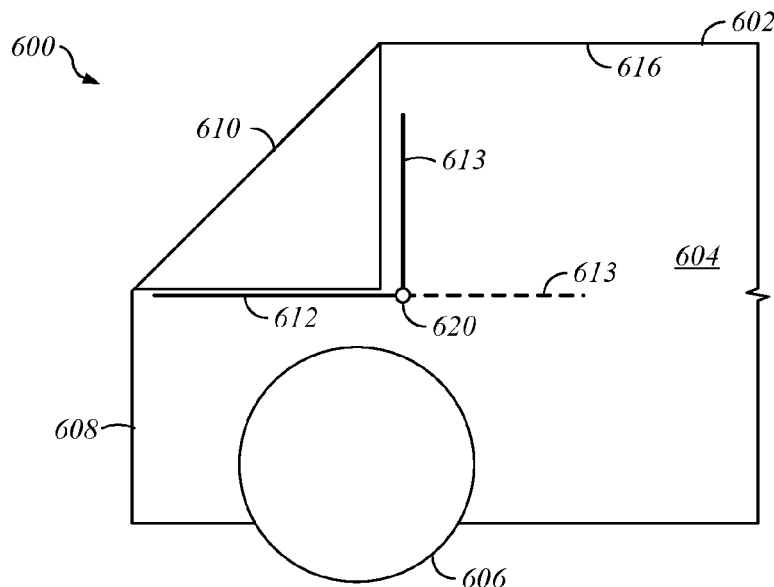
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(57) **ABSTRACT**

An apparatus for resisting entry of objects through a windshield of a vehicle that has a passenger cabin. The apparatus includes an instrument panel that is located between the windshield and the passenger cabin, and an airbag that is deployable into an area above the instrument panel to resist entry of objects into the passenger cabin.

20 Claims, 17 Drawing Sheets



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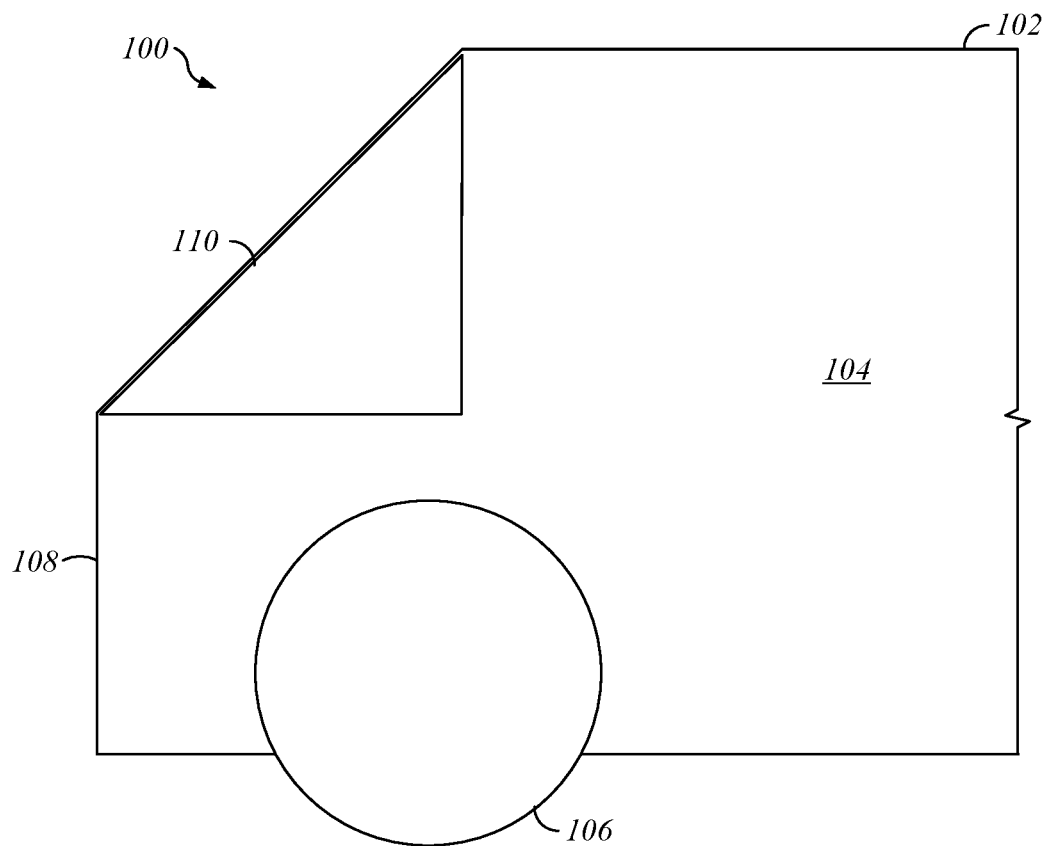


FIG. 1

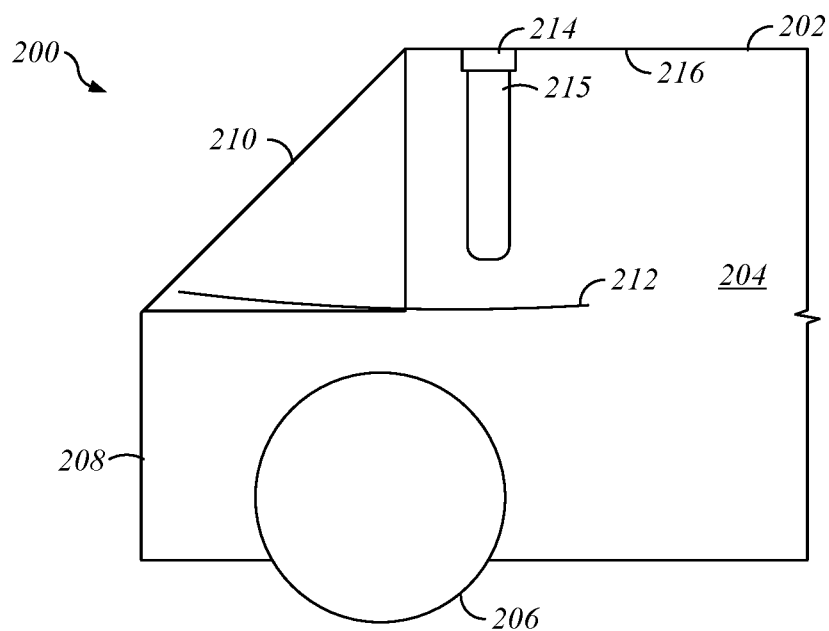


FIG. 2A

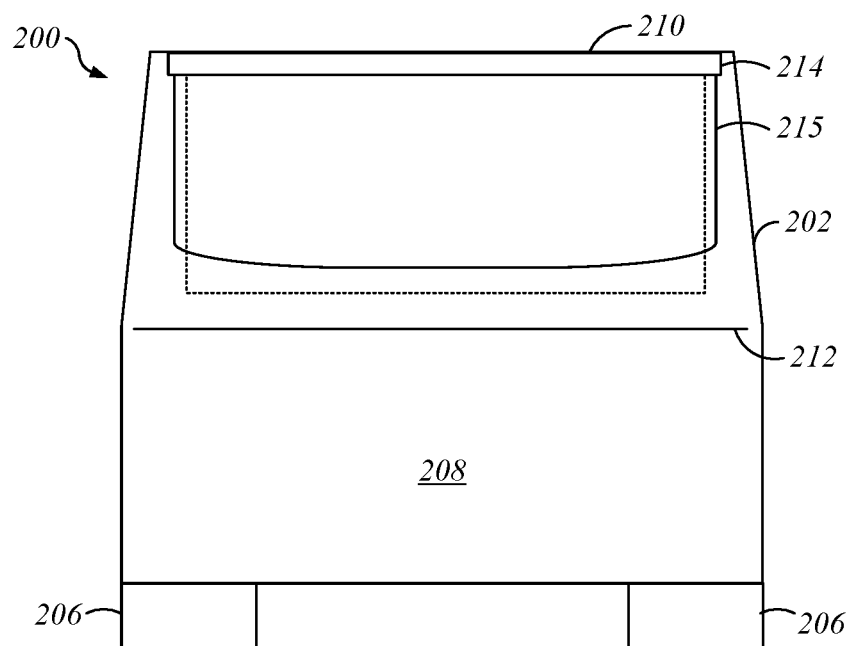


FIG. 2B

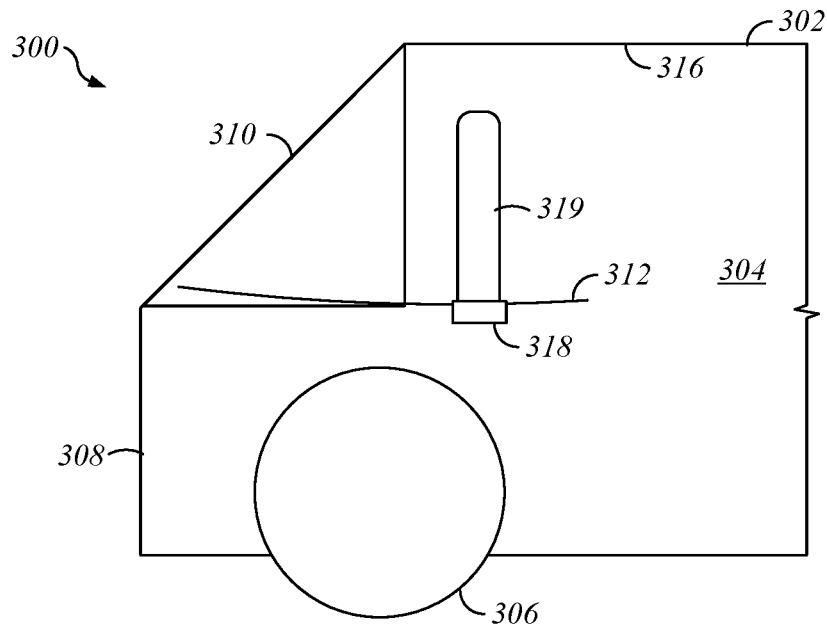


FIG. 3A

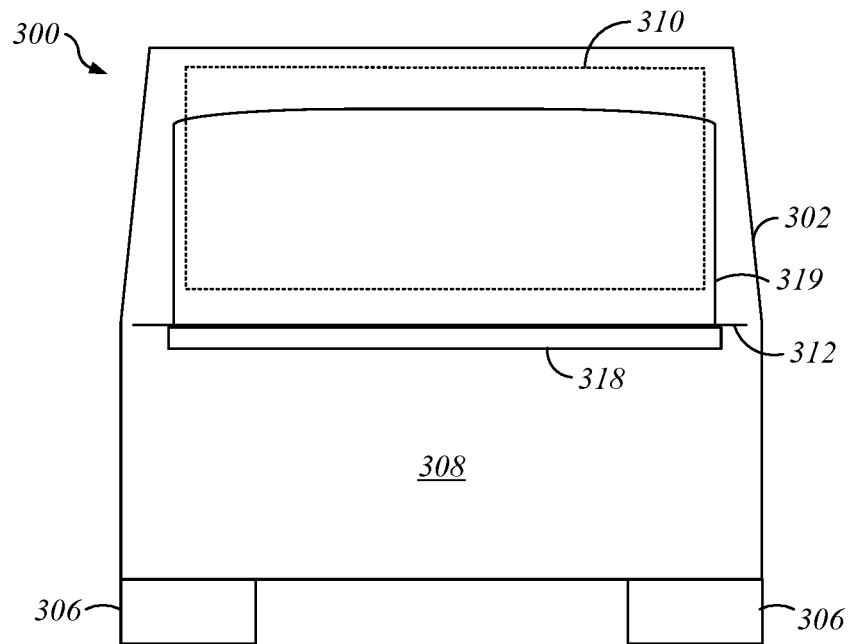


FIG. 3B

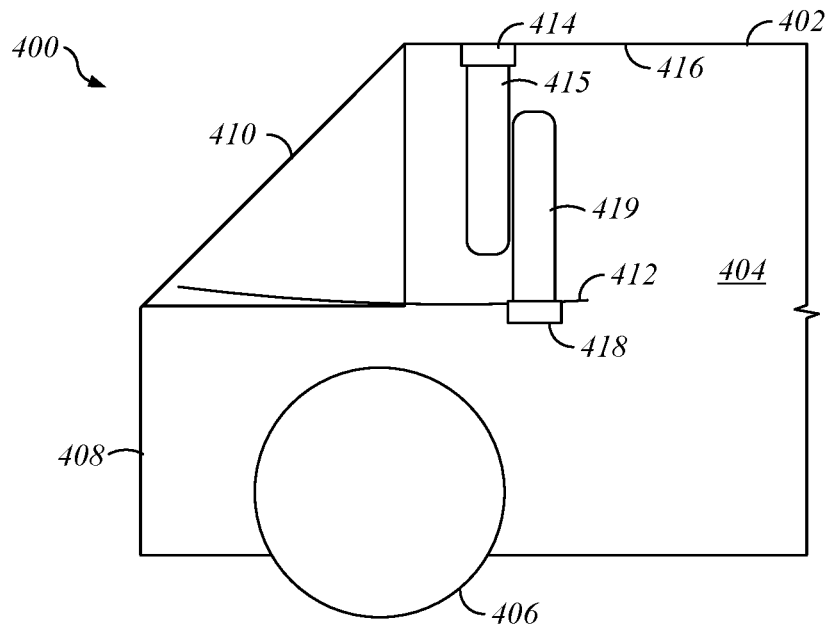


FIG. 4A

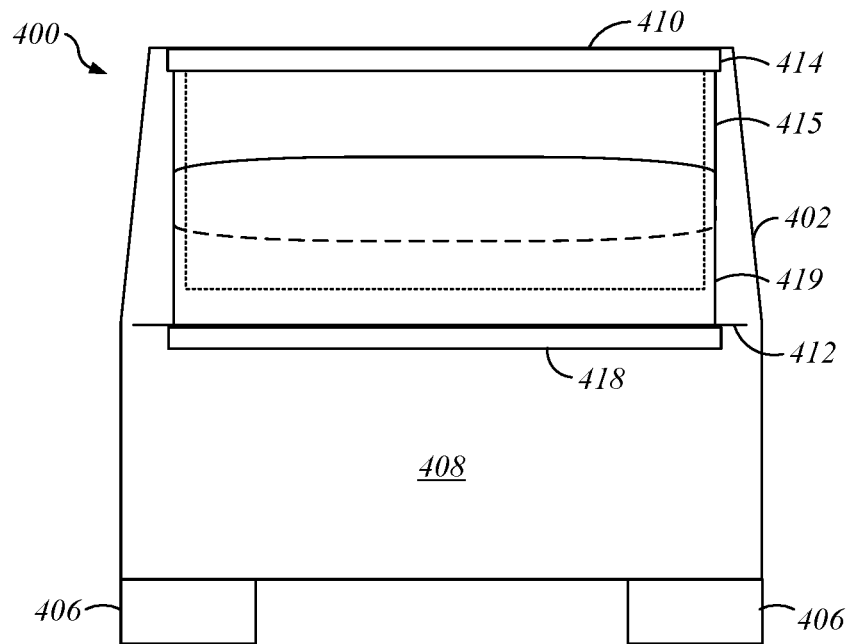


FIG. 4B

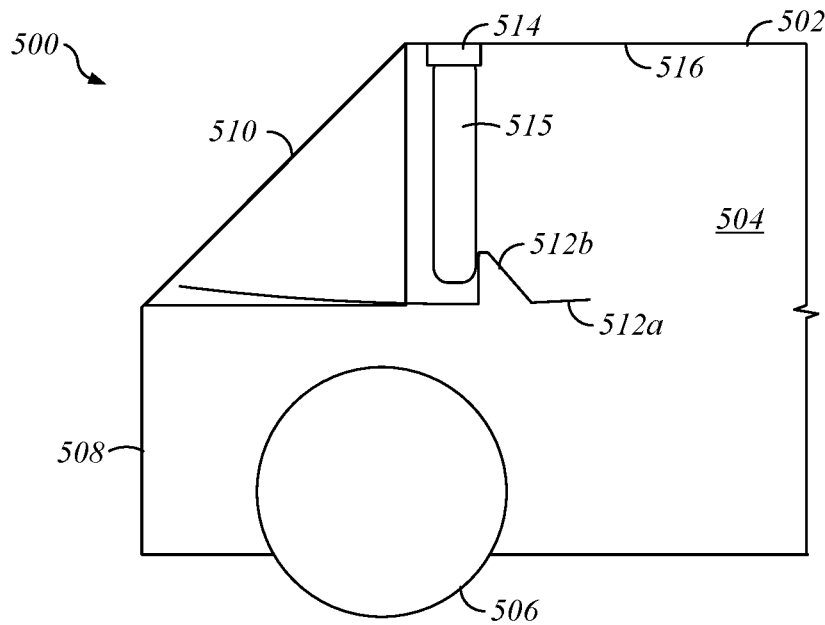


FIG. 5A

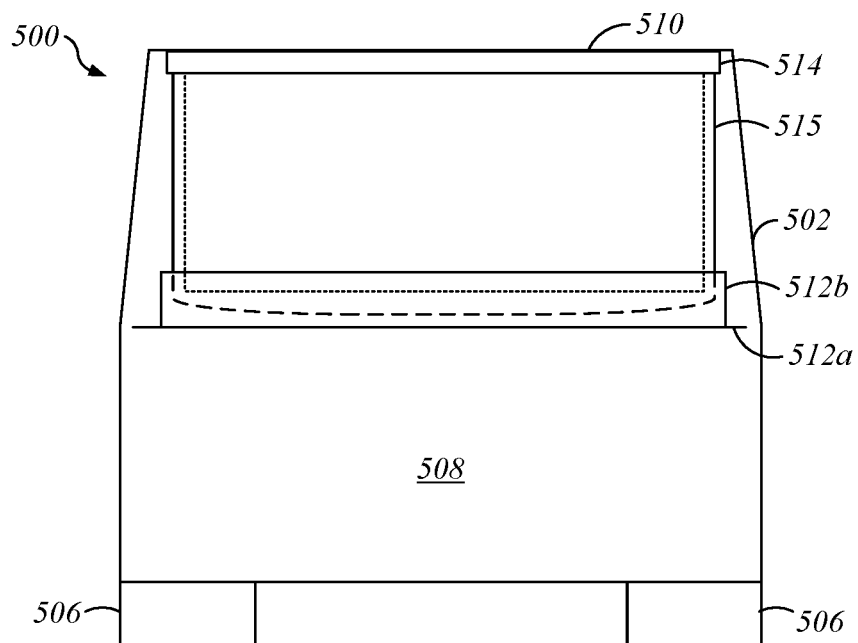
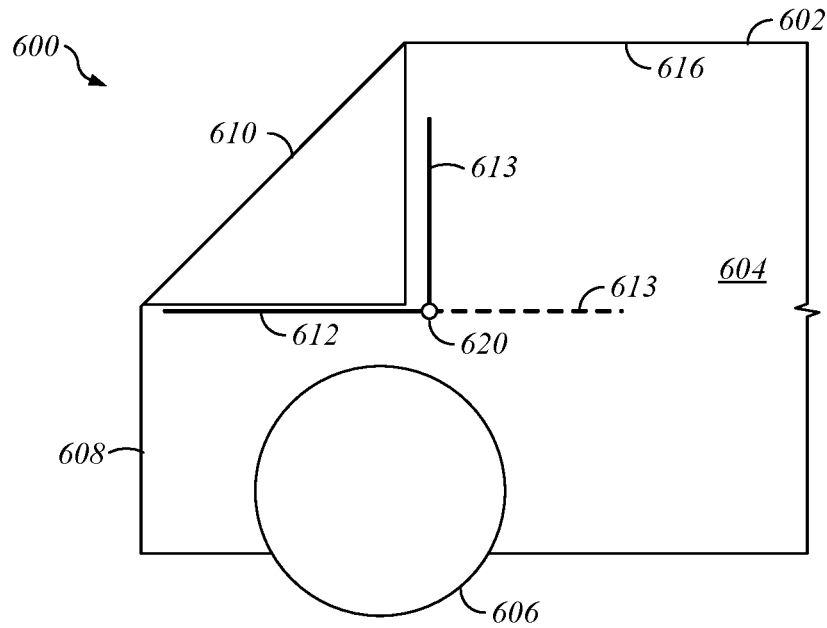
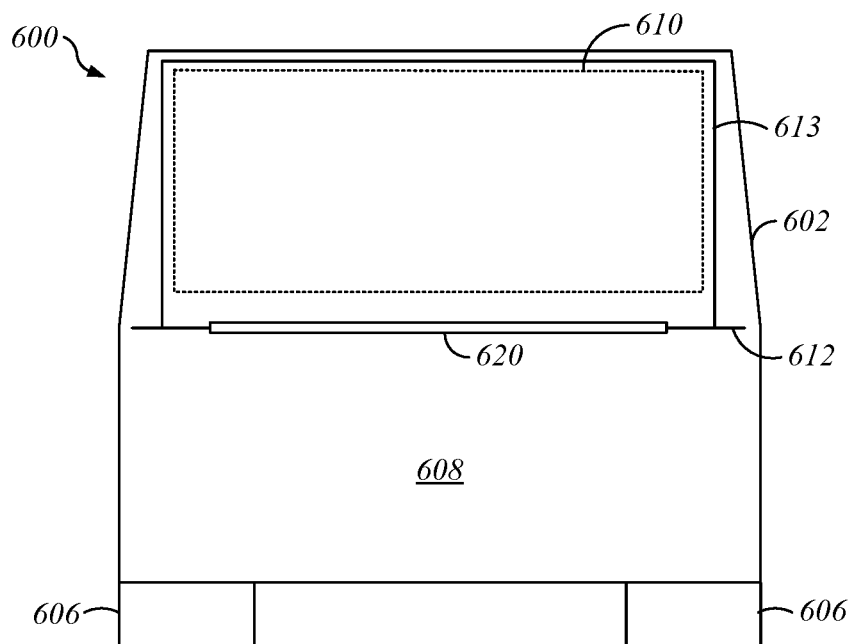


FIG. 5B

**FIG. 6A****FIG. 6B**

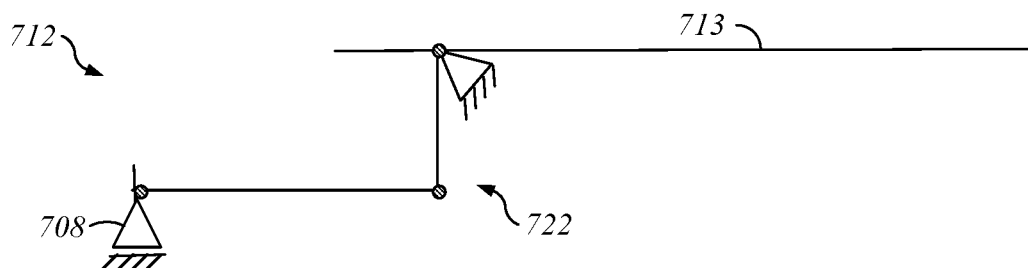


FIG. 7A

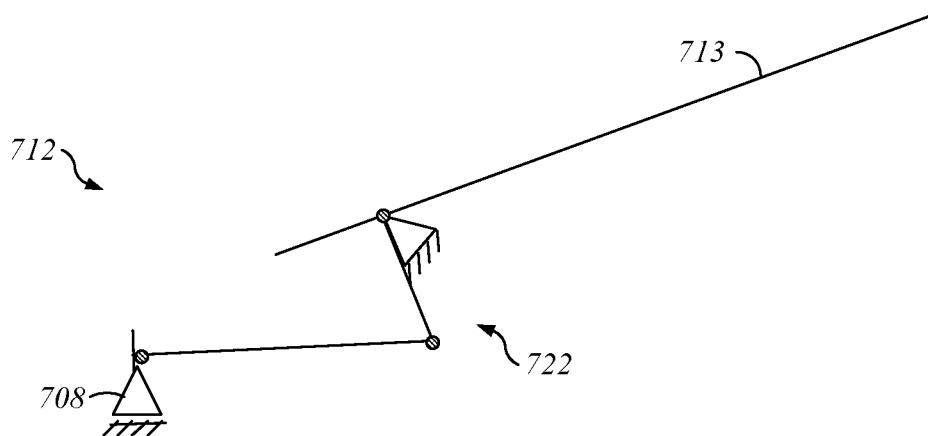


FIG. 7B

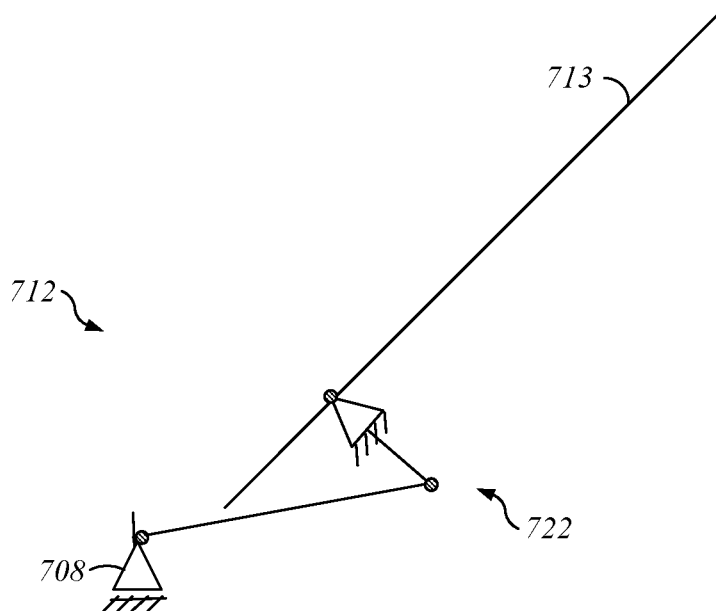


FIG. 7C

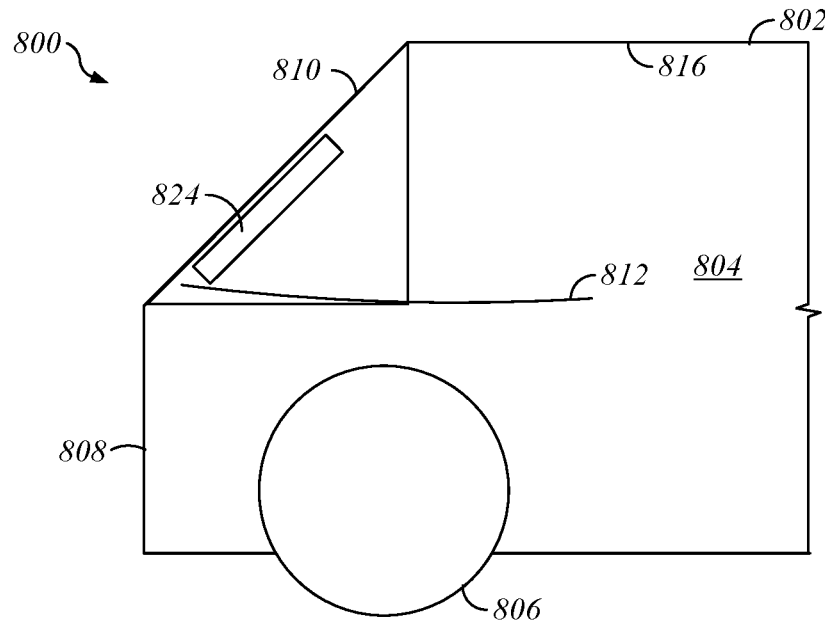


FIG. 8A

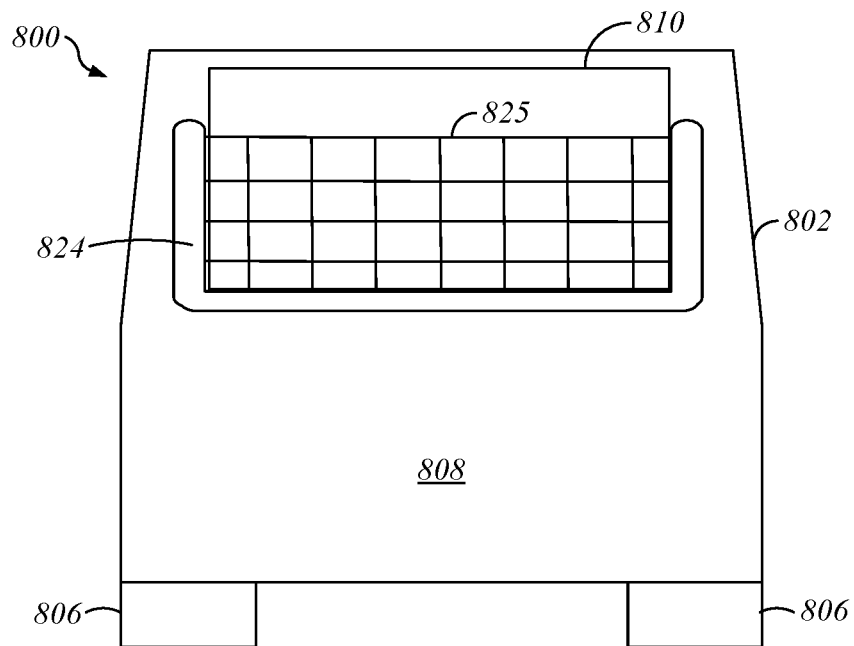


FIG. 8B

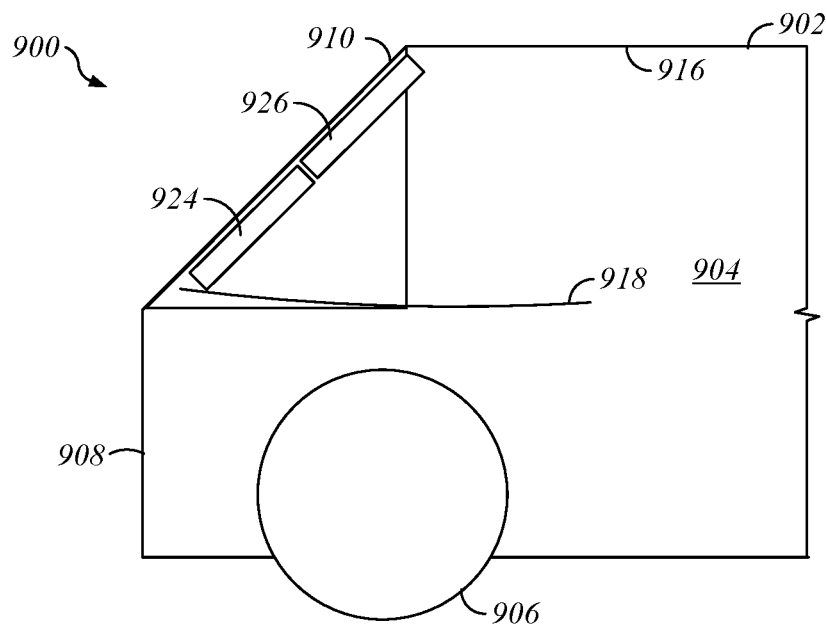


FIG. 9A

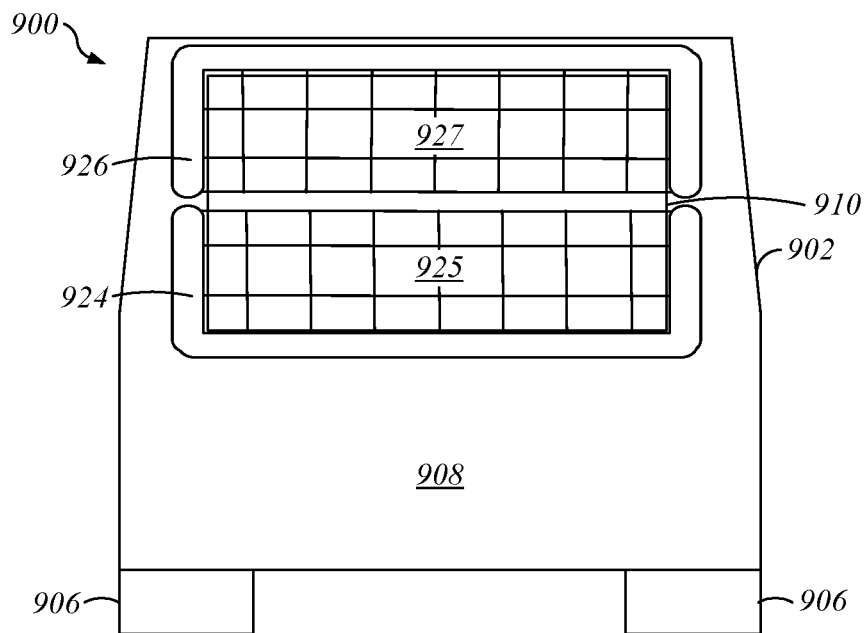


FIG. 9B

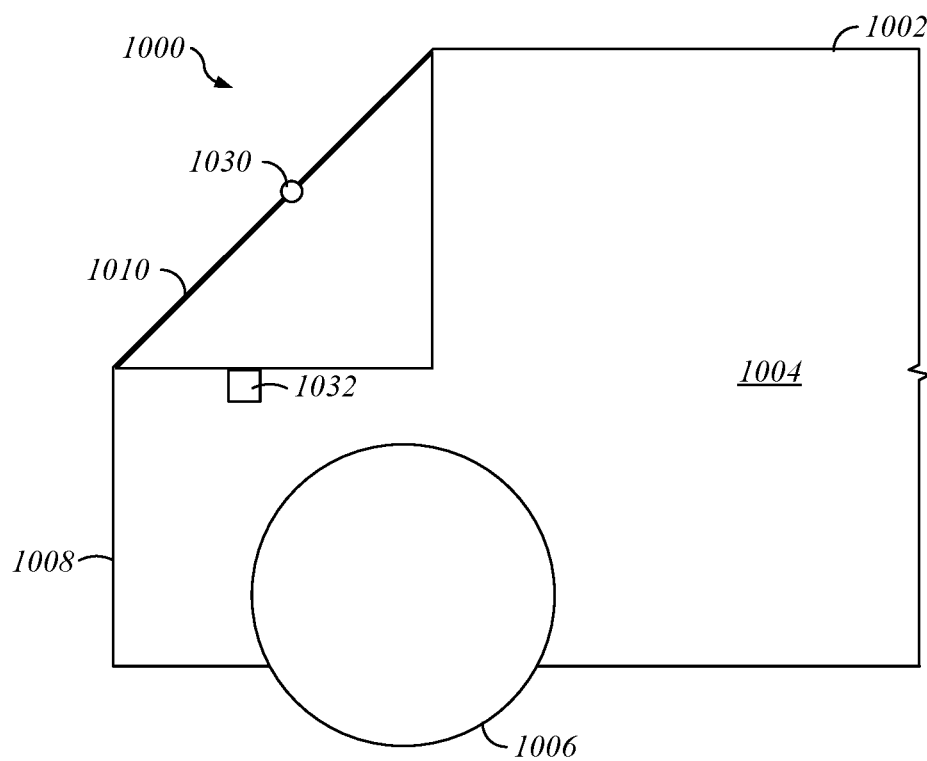


FIG. 10A

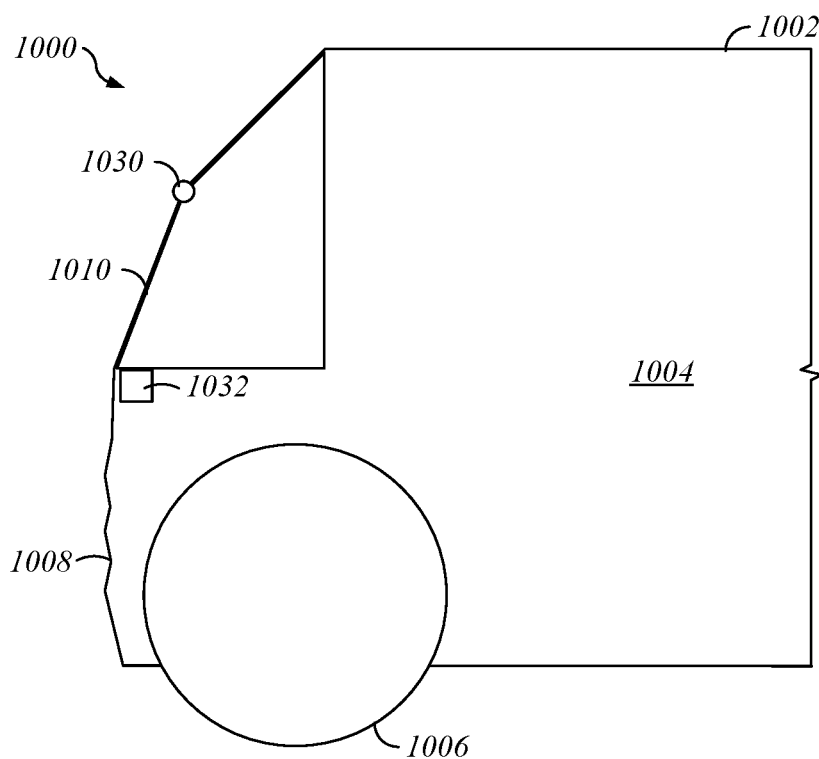


FIG. 10B

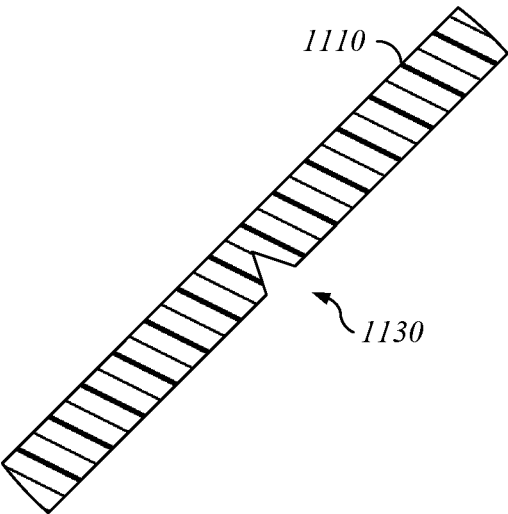


FIG. 11

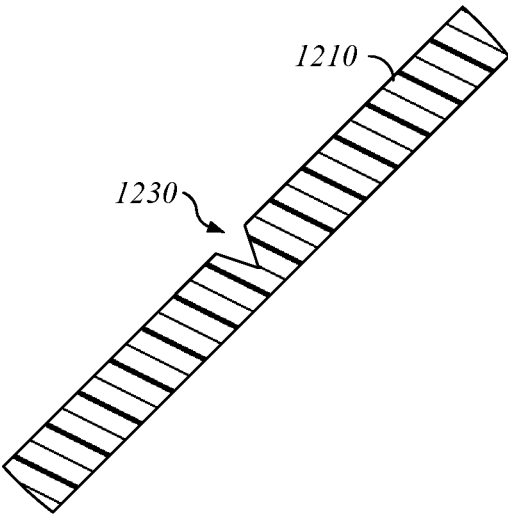


FIG. 12

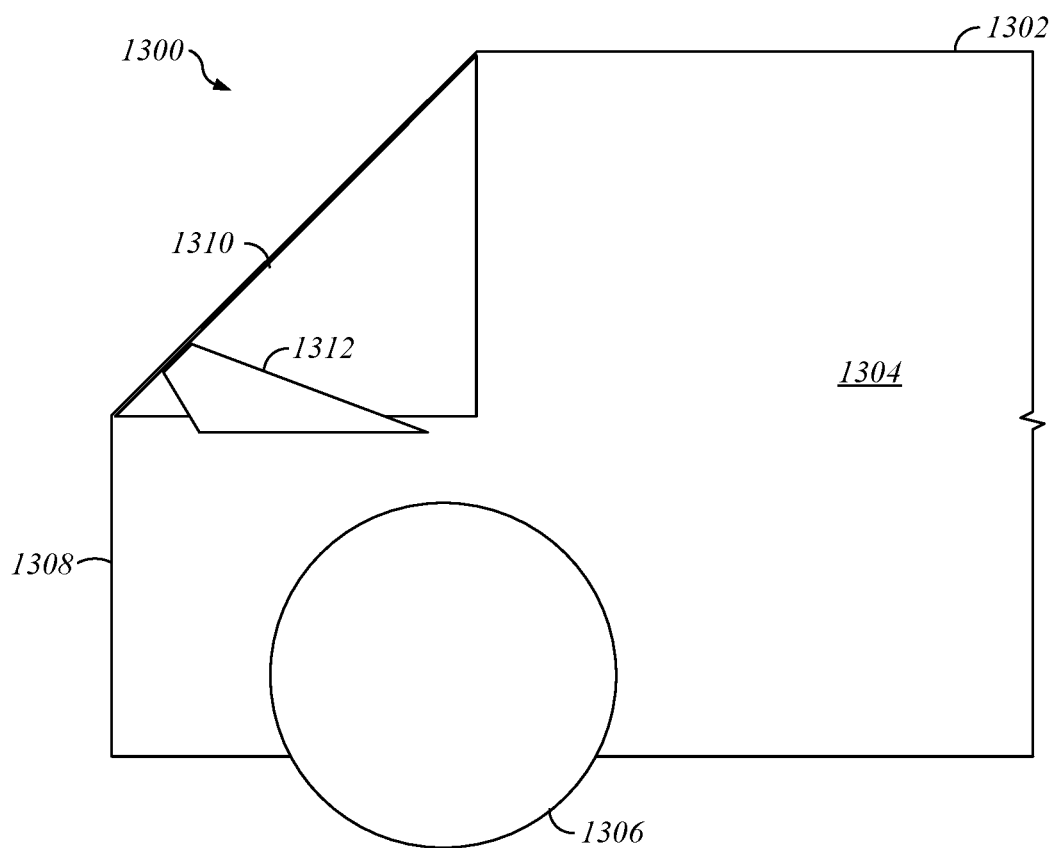


FIG. 13

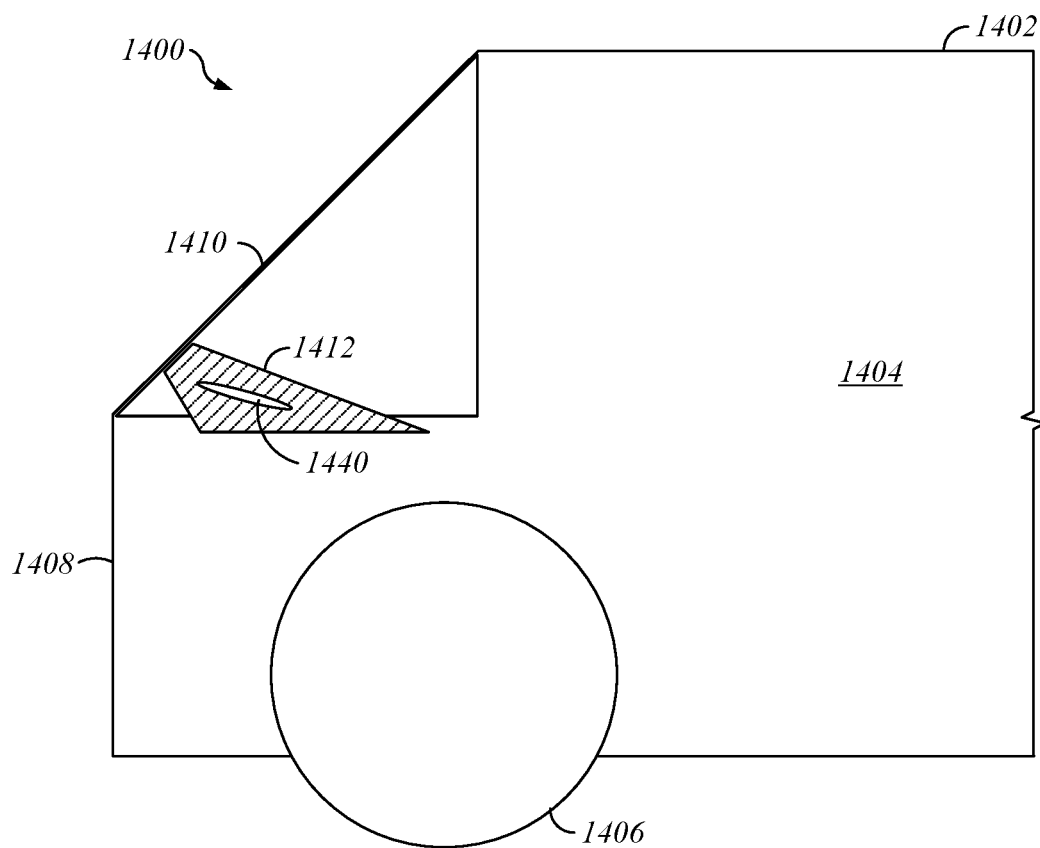


FIG. 14A

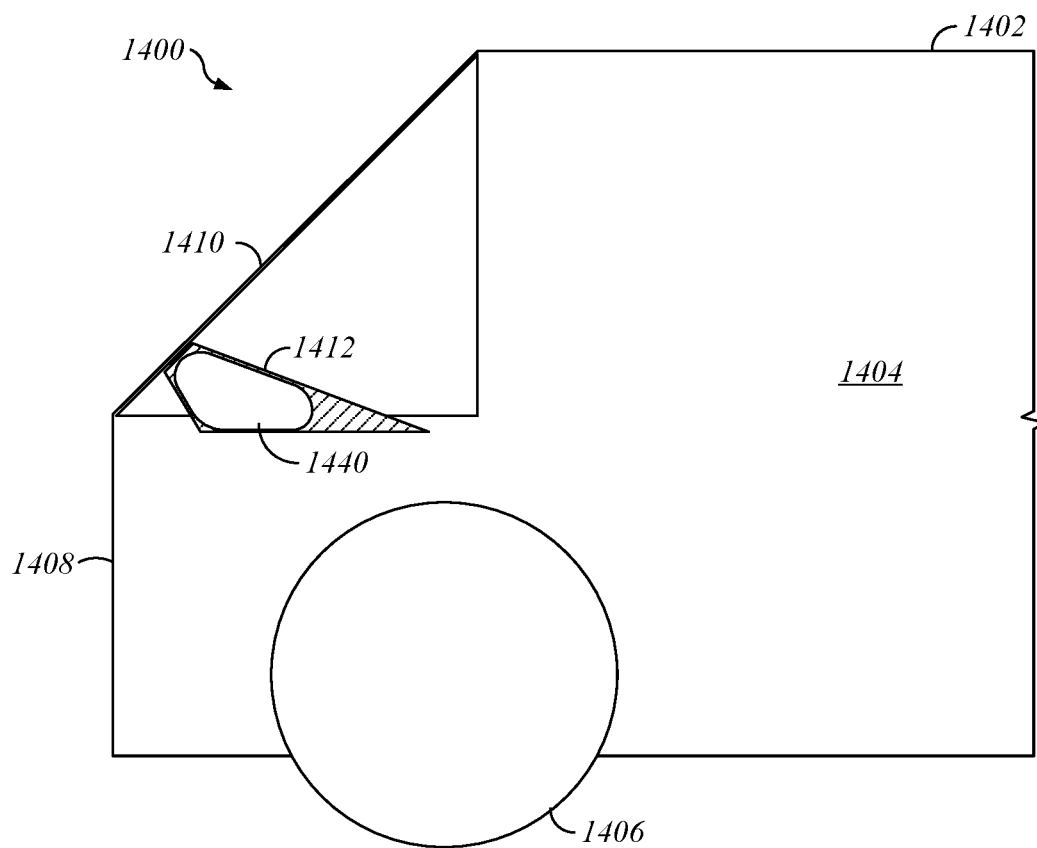


FIG. 14B

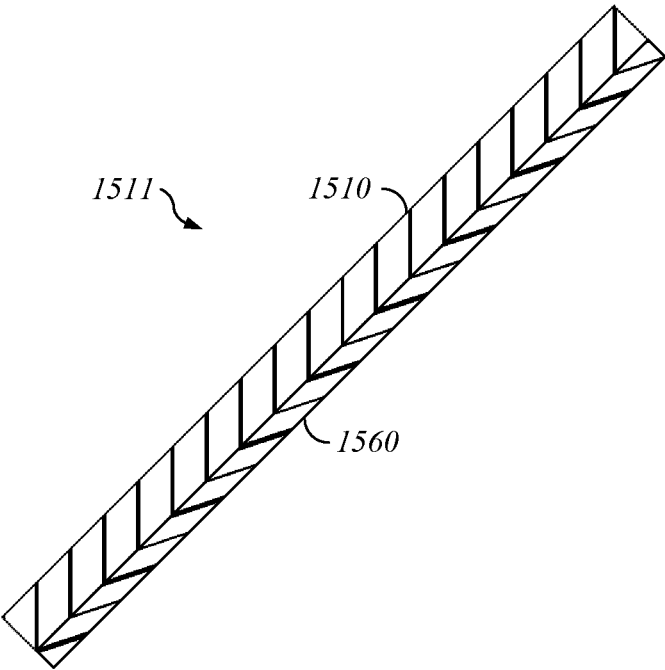


FIG. 15

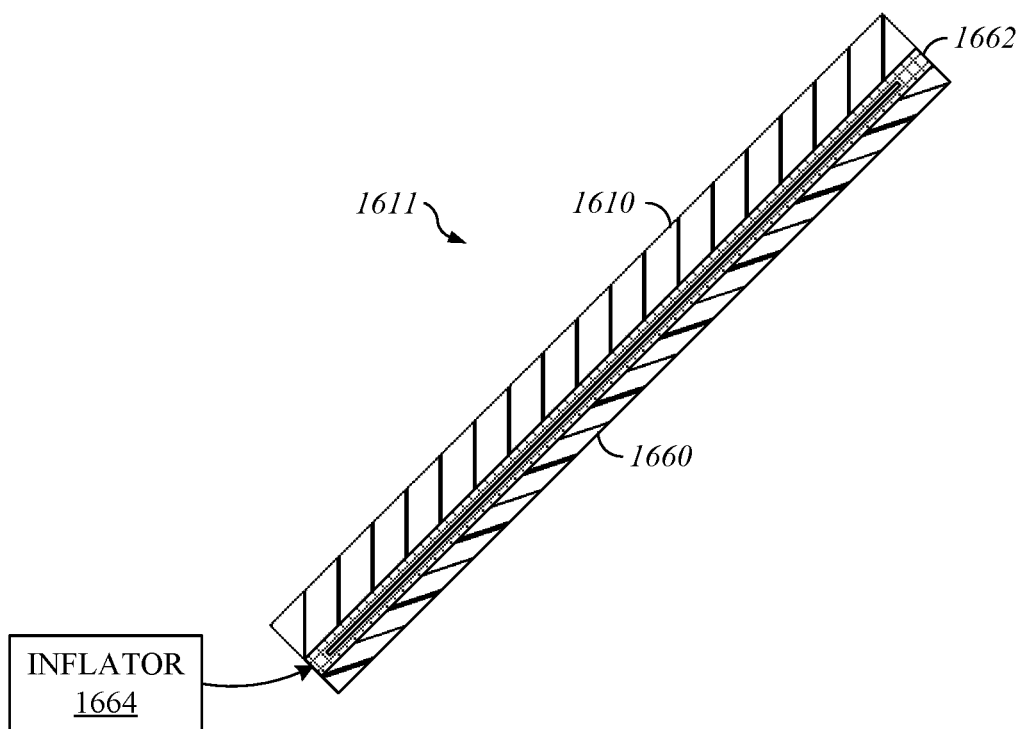


FIG. 16A

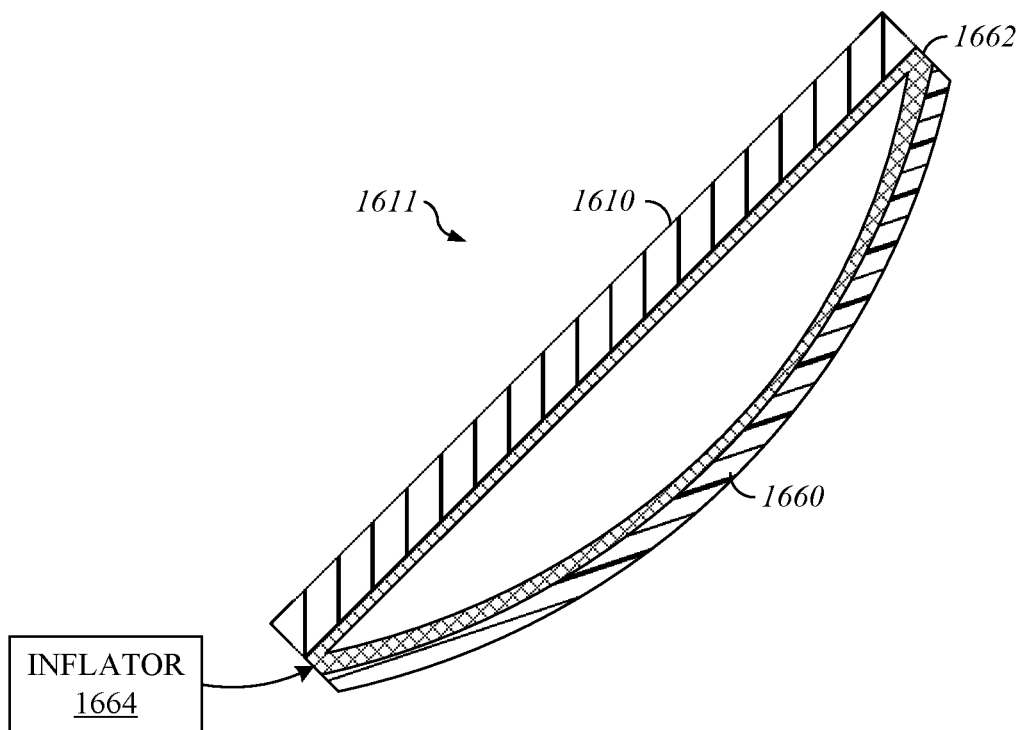
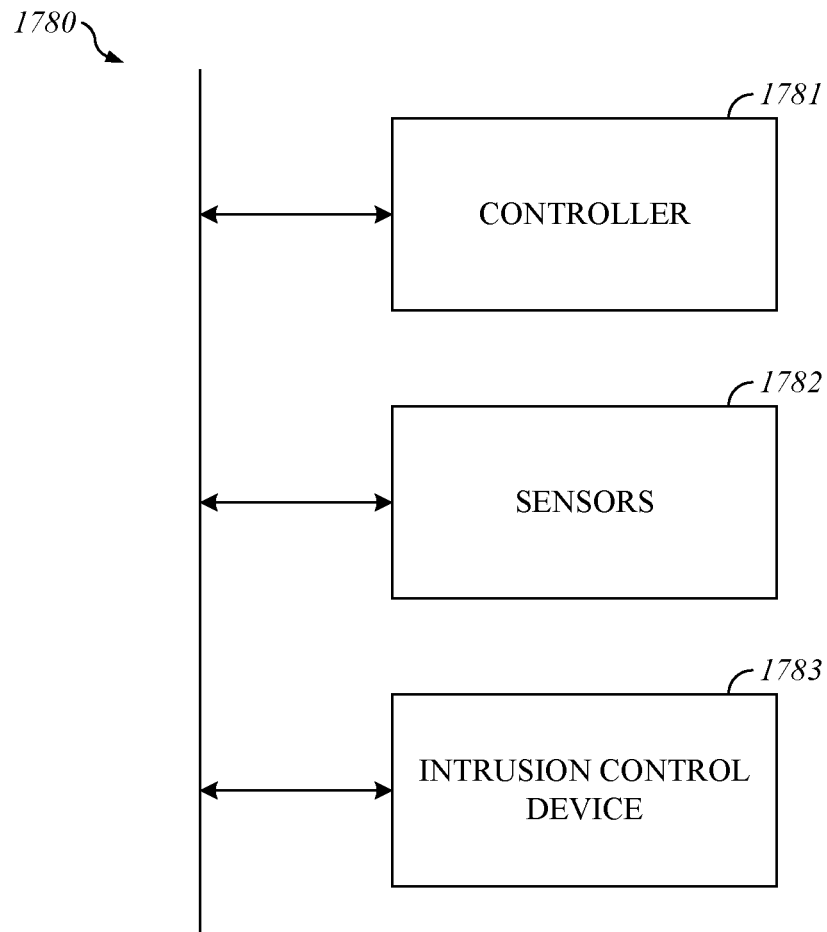


FIG. 16B

**FIG. 17**

WINDSHIELD AREA INTRUSION CONTROL**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims the benefit of U.S. Provisional Application No. 62/527,294, filed on Jun. 30, 2017, and entitled "Windshield Area Intrusion Control." This application also claims the benefit of U.S. Provisional Application No. 62/575,593, filed on Oct. 23, 2017, and entitled "Windshield Area Intrusion Control." The contents of the foregoing applications are incorporated by reference herein in their entireties for all purposes.

TECHNICAL FIELD

The application relates generally to windshields for vehicles.

BACKGROUND

During a vehicular crash, portions of a vehicle will deform upon impact with other objects. A vehicle can be configured to reduce or eliminate entry of structures, such as exterior body components, into a passenger cabin of the vehicle. As an example, crush zones may be designed to allow longitudinal crushing along the hood or fenders of the vehicle in a manner that reduces the likelihood that components will intrude into the passenger cabin. In many jurisdictions, vehicle safety regulations require that no exterior parts of a vehicle intrude into the passenger cabin during a crash. Crash testing, such as a frontal impact with a fixed structure, may be performed to confirm compliance with these regulations.

SUMMARY

One aspect of the disclosed embodiments is an apparatus for resisting entry of objects through a windshield of a vehicle that has a passenger cabin. The apparatus includes an instrument panel that is located between the windshield and the passenger cabin, and an airbag that is deployable into an area above the instrument panel to resist entry of objects into the passenger cabin.

Another aspect of the disclosed embodiments is an apparatus for resisting entry of objects through a windshield of a vehicle that has a passenger cabin. The apparatus includes a panel housing located at a periphery of the windshield, and a deployable panel that deploys from the panel housing in response to a detected impact or an imminent impact to cover a portion of the windshield.

Another aspect of the disclosed embodiments is an apparatus for resisting entry of objects through a windshield of a vehicle that has a passenger cabin. The apparatus includes a fractureable feature that extends laterally across a width dimension of the windshield, and a stop structure that extends laterally across the windshield to limit deformation of a front portion of the vehicle.

Another aspect of the disclosed embodiments is an apparatus for resisting entry of objects through a windshield of a vehicle that has a passenger cabin. The apparatus includes an instrument panel that is formed in part from a compressible structure that, during an impact, is engaged and compressed by the windshield.

Another aspect of the disclosed embodiments is an apparatus for resisting entry of objects through a windshield of a

vehicle that has a passenger cabin. The apparatus includes a film layer located on an interior surface of the windshield.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration that shows a portion of a vehicle.

FIG. 2A is a side view illustration that shows a vehicle in which an upper airbag is deployable such that it is positioned between a windshield and a passenger cabin.

FIG. 2B is a rear-view illustration that shows the vehicle of FIG. 2A.

FIG. 3A is a side view illustration that shows a vehicle in which a lower airbag is deployable such that it is positioned between a windshield and a passenger cabin.

FIG. 3B is a rear-view illustration that shows the vehicle of FIG. 3A.

FIG. 4A is a side view illustration that shows a vehicle in which an upper airbag and a lower airbag are deployable such that they are positioned between a windshield and a passenger cabin.

FIG. 4B is a rear-view illustration that shows the vehicle of FIG. 4A.

FIG. 5A is a side view illustration that shows a vehicle in which an upper airbag is deployable such that it is engageable with a reaction surface and is positioned between a windshield and a passenger cabin.

FIG. 5B is a rear-view illustration that shows the vehicle of FIG. 5A.

FIG. 6A is a side view illustration that shows a vehicle in which an instrument panel has a moveable portion.

FIG. 6B is a rear-view illustration that shows the vehicle of FIG. 6A.

FIG. 7A shows an example of a moveable instrument panel in a lowered position.

FIG. 7B shows the moveable instrument panel of FIG. 7A in an intermediate position.

FIG. 7C shows the moveable instrument panel of FIG. 7A in a raised position.

FIG. 8A is a side view illustration that shows a vehicle that includes a deployable panel.

FIG. 8B is a rear-view illustration that shows the vehicle of FIG. 8A.

FIG. 9A is a side view illustration that shows a vehicle that includes a deployable panel.

FIG. 9B is a rear-view illustration that shows the vehicle of FIG. 9A.

FIG. 10A shows a vehicle in an initial condition.

FIG. 10B shows the vehicle of FIG. 10A in a deformed condition.

FIG. 11 shows a first example of a defined notch on an interior surface of a windshield.

FIG. 12 shows a second example of a defined notch on an exterior surface of a windshield.

FIG. 13 shows a vehicle that has a compressible instrument panel.

FIG. 14A shows a vehicle that has a compressible instrument panel and an inflatable portion in an uninflated condition.

FIG. 14B shows the vehicle of FIG. 14A with the inflatable portion of the compressible instrument panel in an inflated condition.

FIG. 15 shows a vehicle windshield assembly that has a film layer.

FIG. 16A show a windshield assembly that has a film layer and a transparent inflatable structure in an uninflated condition.

FIG. 16B shows the windshield assembly of FIG. 16A with the transparent inflatable structure in the inflated condition.

FIG. 17 is a block diagram that shows an intrusion control system

DETAILED DESCRIPTION

The disclosure herein is directed to structures that resist intrusion of objects into the passenger cabin of a vehicle during an impact.

In vehicle designs in which a windshield is positioned near a front extent of the vehicle, the windshield may experience large deformations during an impact, in order to dissipate energy. The structures disclosed herein are intended to resist intrusion of objects into the vehicle from the windshield area during large deformations of the windshield.

FIG. 1 is an illustration that shows a portion of a vehicle 100. The vehicle 100 includes a vehicle body 102, which may be or include a chassis, frame, unibody, monocoque, and/or exterior panels. A passenger cabin 104 is defined inside the vehicle body 102. The vehicle 100 may be supported with respect to a surface (e.g., a road) by wheels 106, and control of the vehicle may be affected through the wheels using actuators such as steering, propulsion, braking, and suspension actuators.

The vehicle 100 has a front portion 108, which defines a front extent of the vehicle 100. In a frontal impact with an object, the front portion 108 of the vehicle 100 may be the first part of the vehicle 100 to contact the object. The vehicle 100 includes a windshield 110. In the illustrated example, the windshield 110 has a raked configuration, with a lower edge of the windshield 110 being positioned at or near the front portion 108 and an upper edge of the windshield 110 being positioned upward and rearward from the lower edge. As an example, a front surface of the windshield 110 may define an angle of around 30 degrees through eighty degrees relative to horizontal. The windshield 110 also extends laterally (i.e., in a cross-car direction) across part of or all of the width of the vehicle 100. In the illustrated example, the windshield 110 has a wrap-around configuration in which portions of the windshield 110 extend to and along the side surfaces of the vehicle 100, but other configurations can also be utilized with the structures described herein.

FIGS. 2A and 2B show a vehicle 200 that includes components that are analogous to those of the vehicle 100, including a vehicle body 202, a passenger cabin 204, wheels 206, a front portion 208, and a windshield 210. The vehicle 200 also includes an instrument panel 212 that is located inside the vehicle body 202 between the windshield 210 and the passenger cabin 204. The vehicle 200 includes one or more airbags that are deployable such that they are positioned between the windshield 210 and the passenger cabin 204. In some implementations, the airbags are disposed entirely over the instrument panel 212, forward from the passenger cabin 204, and do not extend into the passenger cabin 204.

An upper airbag housing 214 is located on an interior surface of a roof 216 of the vehicle body 202. The upper airbag housing 214 may extend across most of or all of the lateral direction of the vehicle 200. An upper airbag 215 is deployable from the upper airbag housing 214, for example, in response to a detected impact or an imminent impact. When deployed, the upper airbag 215 extends downward from the upper airbag housing 214 from the roof 216 toward the instrument panel 212 and extends across most of or all

of the lateral direction of the vehicle 200. As an example, the upper airbag 215 may extend across at least ninety percent of an interior width of the vehicle 200 in the lateral direction. The upper airbag 215 may extend all of the way from the upper airbag housing 214 to the instrument panel 212. The upper airbag 215, when deployed may occupy a majority of the width of the vehicle 200 and a majority of the height between the instrument panel 212 and the roof 216, to separate the windshield 210 from the passenger cabin 204.

FIGS. 3A and 3B show a vehicle 300 that includes components that are analogous to those of the vehicle 100, including a vehicle body 302, a passenger cabin 304, wheels 306, a front portion 308, and a windshield 310. The vehicle 300 also includes an instrument panel 312 that is located inside the vehicle body 302 between the windshield 310 and the passenger cabin 304. The vehicle 300 includes one or more airbags that are deployable such that they are positioned between the windshield 310 and the passenger cabin 304. In some implementations, the airbags are disposed entirely over the instrument panel 312, forward from the passenger cabin 304, and do not extend into the passenger cabin 304.

A lower airbag housing 318 is located on or in the instrument panel 312 (e.g., concealed under a surface of the instrument panel 312). The lower airbag housing 318 may extend across most of or all of the lateral direction of the vehicle 300. A lower airbag 319 is deployable from the lower airbag housing 318, for example, in response to a detected impact or an imminent impact. When deployed, the lower airbag 319 extends upward from the lower airbag housing 318 from the instrument panel 312 toward the roof 316 and extends across most of or all of the lateral direction of the vehicle 300. As an example, the lower airbag 319 may extend across at least ninety percent of an interior width of the vehicle 300 in the lateral direction. The lower airbag 319 may extend all of the way from the lower airbag housing 318 to the roof 316. The lower airbag 319, when deployed, may occupy a majority of the width of the vehicle 300 and a majority of the height between the instrument panel 312 and the roof 316, to separate the windshield 310 from the passenger cabin 304.

FIGS. 4A and 4B show a vehicle 400 that includes components that are analogous to those of the vehicle 100, including a vehicle body 402, a passenger cabin 404, wheels 406, a front portion 408, and a windshield 410. The vehicle 400 also includes an instrument panel 412 that is located inside the vehicle body 402 between the windshield 410 and the passenger cabin 404. The vehicle 400 includes one or more airbags that are deployable such that they are positioned between the windshield 410 and the passenger cabin 404. In some implementations, the airbags are disposed entirely over the instrument panel 412, forward from the passenger cabin 404, and do not extend into the passenger cabin 404.

An upper airbag housing 414 is located on an interior surface of a roof 416 of the vehicle body 402. The upper airbag housing 414 may extend across most of or all of the lateral direction of the vehicle 400. An upper airbag 415 is deployable from the upper airbag housing 414, for example, in response to a detected impact or an imminent impact. When deployed, the upper airbag 415 extends downward from the upper airbag housing 414 from the roof 416 toward the instrument panel 412 and extends across most of or all of the lateral direction of the vehicle 400. As an example, the upper airbag 415 may extend across at least ninety percent of an interior width of the vehicle 400 in the lateral direction. The upper airbag 415 may extend all of the way from the

5

upper airbag housing 414 to the instrument panel 412. The upper airbag 415, when deployed may occupy a majority of the width of the vehicle 400 and a majority of the height between the instrument panel 412 and the roof 416, to separate the windshield 410 from the passenger cabin 404.

A lower airbag housing 418 is located on or in the instrument panel 412 (e.g., concealed under a surface of the instrument panel 412). The lower airbag housing 418 may extend across most of or all of the lateral direction of the vehicle 400. A lower airbag 419 is deployable from the lower airbag housing 418, for example, in response to a detected impact or an imminent impact. When deployed, the lower airbag 419 extends upward from the lower airbag housing 418 from the instrument panel 412 toward the roof 416 and extends across most of or all of the lateral direction of the vehicle 400. As an example, the lower airbag 419 may extend across at least ninety percent of an interior width of the vehicle 400 in the lateral direction. The lower airbag 419 may extend all of the way from the lower airbag housing 418 to the roof 416. The lower airbag 419, when deployed, may occupy a majority of the width of the vehicle 400 and a majority of the height between the instrument panel 412 and the roof 416, to separate the windshield 410 from the passenger cabin 404.

The upper airbag housing 414 and the lower airbag housing 418 are slightly offset in a longitudinal direction (e.g., front-to-rear direction). When deployed, the upper airbag 415 and the lower airbag 419 overlap elevationally, and may engage one another to separate the windshield 410 from the passenger cabin 404.

FIGS. 5A and 5B show a vehicle 500 that includes components that are analogous to those of the vehicle 100, including a vehicle body 502, a passenger cabin 504, wheels 506, a front portion 508, and a windshield 510. The vehicle 500 also includes an instrument panel 512a that is located inside the vehicle body 502 between the windshield 510 and the passenger cabin 504. The vehicle 500 includes one or more airbags that are deployable such that they are positioned between the windshield 510 and the passenger cabin 504. In some implementations, the airbags are disposed entirely over the instrument panel 512a, forward from the passenger cabin 504, and do not extend into the passenger cabin 504.

An upper airbag housing 514 is located on an interior surface of a roof 516 of the vehicle body 502. The upper airbag housing 514 may extend across most of or all of the lateral direction of the vehicle 500. An upper airbag 515 is deployable from the upper airbag housing 514, for example, in response to a detected impact or an imminent impact. When deployed, the upper airbag 515 extends downward from the upper airbag housing 514 from the roof 516 toward the instrument panel 512a and extends across most of or all of the lateral direction of the vehicle 500. As an example, the upper airbag 515 may extend across at least ninety percent of an interior width of the vehicle 500 in the lateral direction. The upper airbag 515 may extend all of the way from the upper airbag housing 514 to the instrument panel 512. The upper airbag 515, when deployed may occupy a majority of the width of the vehicle 500 and a majority of the height between the instrument panel 512a and the roof 516, to separate the windshield 510 from the passenger cabin 504. To provide a reaction surface for the upper airbag 515, a protrusion 512b extends upward relative to the remainder of the instrument panel 512a, and includes a surface that is engageable with the upper airbag 515 when it is deployed, to resist movement of the upper airbag 515 toward the passenger cabin 504.

6

FIGS. 6A-6B show a vehicle 600 in which an instrument panel has a moveable portion. The vehicle 600 includes components that are analogous to those of the vehicle 100, including a vehicle body 602, a passenger cabin 604, wheels 606, a front portion 608, and a windshield 610. The vehicle 600 also includes an instrument panel 612 that is located inside the vehicle body 602 between the windshield 610 and the passenger cabin 604. The vehicle body 602 of the vehicle 600 includes a roof 616.

The instrument panel 612 includes a moveable portion 613 that defines a lowered position (depicted in broken lines) and a raised position (depicted in solid lines). The moveable portion 613 pivots with respect to the remainder of the instrument panel 612 (which may be fixed) at a joint 620, which may be, as examples, a pin connected joint or a living hinge. The moveable portion 613 may move from the lowered position to the raised position in response to a detected impact or an imminent impact. The moveable portion 613 may be moved by, as examples, a mechanical actuator (e.g., a spring loaded mechanical actuator) or a pyrotechnic actuator. When in the raised position, the moveable portion 613 serves as a separation device that is located between the windshield 610 and the passenger cabin 604. The moveable portion 613 of the instrument panel 612, when deployed, may occupy a majority of the width of the vehicle 600 and a majority of the height between the instrument panel 612 and the roof 616, to separate the windshield 610 from the passenger cabin 204.

Optionally, the upper airbag housing 214 and the upper airbag 215 of the vehicle 200 could be included in the vehicle 600, such that the moveable portion 613 of the instrument panel 612 serves as a reaction surface for the upper airbag 215 when the moveable portion 613 of the instrument panel 612 is in the raised position.

FIGS. 7A, 7B, and 7C show an example of an instrument panel 712 having a moveable portion 713 that moves between a lowered position (FIG. 7A), an intermediate position (FIG. 7B), and a raised position (FIG. 7C) under the influence of a coupling 722 to a front portion 708 (shown schematically) of a vehicle. During an impact, the front portion 708 translates in a generally longitudinal direction, which causes rotation of the coupling 722 relative to the front portion 708. The coupling 722 is rigidly connected to the moveable portion 713 of the instrument panel 712, such that the moveable portion 713 rotates from the lowered position, to the intermediate position, and to the raised position during translation of the front portion 708.

FIGS. 8A-8B show a vehicle 800 that includes components that are analogous to those of the vehicle 100, including a vehicle body 802, a passenger cabin 804, wheels 806, a front portion 808, a windshield 810, an instrument panel 812, and a roof 816. The vehicle 800 includes, in various implementations, a deployable panel, which can be a sheet of material, such as netting, plastic, or fabric, that is stored around the windshield 810 and deploys in response to a detected impact or an imminent impact. Deployment of the deployable panel can be driven by an inflatable pyrotechnic device, a linear pyrotechnic device, or a mechanical spring actuator.

The vehicle 800 includes a first panel housing 824 is located at a periphery of the windshield 810, below the windshield 810 and at the lateral sides of the windshield 810. A first panel 825 is deployable from the first panel housing 824 to cover a portion of the windshield 810 on the interior of the vehicle 800 to restrain intrusion of objects into the passenger cabin. The first panel 825 can extend, for example, across the lateral width of the windshield 810 and

from a lower edge of the windshield **810** upward to or past an elevational midpoint of the windshield **810**.

FIGS. 9A-9B show a vehicle **900** that includes components that are analogous to those of the vehicle **100**, including a vehicle body **902**, a passenger cabin **904**, wheels **906**, a front portion **908**, and a windshield **910**. The vehicle **900** includes, in various implementations, a deployable panel, which can be a sheet of material, such as netting, plastic, or fabric, that is stored around the windshield **910** and deploys in response to a detected impact or an imminent impact. Deployment of the deployable panel can be driven by an inflatable pyrotechnic device, a linear pyrotechnic device, or a mechanical spring actuator.

The vehicle **900** includes a first panel housing **924** and a first panel **925**, which are the same as the first panel housing **824** and the first panel **825** of the vehicle **800**. The vehicle **900** also includes a second panel housing **926**, and a second panel **927**. The second panel housing **926** is located at a periphery of the windshield **910**, above the windshield **910** and at the lateral sides of the windshield **910**. The second panel **927** is deployable from the second panel housing **926** to cover a portion of the windshield **910** on the interior of the vehicle **900** to restrain intrusion of objects into the passenger cabin. The second panel **927** can extend, for example, across the lateral width of the windshield **910** and from a lower edge of the windshield **910** downward to or past an elevational midpoint of the windshield **910**. In one implementation, the first panel **925** and the second panel **927** meet near the elevational midpoint of the windshield **910** when deployed. In another implementation, the first panel **925** and the second panel **927** each extend past the elevational midpoint of the windshield **910** when deployed, and overlap each other.

FIGS. 10A-10B show a vehicle **1000** that includes components that are analogous to those of the vehicle **100**, including a vehicle body **1002**, a passenger cabin **1004**, wheels **1006**, a front portion **1008**, and a windshield **1010**. FIG. 10A shows the vehicle **1000** in an initial condition, and FIG. 10B shows the vehicle **1000** in a deformed condition. The vehicle **1000** includes, in various implementations, a fracturable feature **1030** that extends laterally across the width of the windshield **1010** and a stop structure **1032**, which is a structural member that extends laterally across the vehicle **1000** and limits deformation of the front portion **1008** of the vehicle **1000** (see FIG. 10B). The stop structure **1032** may be longitudinally aligned with the fracturable feature **1030** to limit deformation of the front portion **1008** rearward of the fracturable feature **1030**. As one example, the fracturable feature **1030** may be a defined notch to break during impact in order to interrupt the load path through the windshield **1010**. As another example, the fracturable feature **1030** of the windshield **1010** may be a wire that is embedded in the windshield **1010**. As another example, the fracturable feature **1030** may be a pyrotechnic wire that is embedded in the windshield **1010** to break the windshield along a laterally extending line upon activation, for example, in response to a detected impact or an imminent impact. As another example, the fracturable feature **1030** may be omitted in favor of a weakened portion that functions as a living hinge, such that the lower portion of the windshield **1010** rotates about it during an impact.

FIG. 11 shows a first example of a defined notch **1130** on an interior surface of a windshield **1110**, which may be used in the vehicle **1000** in place of the windshield **1010**. The defined notch **1130** extends inward relative to the windshield **1110** from the interior surface of the windshield **1110** toward the exterior surface of the windshield **1010**, and may extend

across the windshield **1110** laterally in a generally horizontal line. Thus, the defined notch **1130** may define an elongate, linear, fracturable feature that provides a predetermined location for fracturing of the windshield **1010**.

FIG. 12 shows a second example of a defined notch **1230** on an exterior surface of a windshield **1210**, which may be used in place of the windshield **1010** in the vehicle **1000**. The defined notch **1230** extends inward relative to the windshield **1210** from the exterior surface of the windshield **1210** toward the interior surface of the windshield **1210**, and may extend across the windshield **1210** laterally in a generally horizontal line. Thus, the defined notch **1230** may define an elongate, linear, fracturable feature that provides a predetermined location for fracturing of the windshield **1210**.

FIG. 13 shows a vehicle **1300** that includes components that are analogous to those of the vehicle **100**, including a vehicle body **1302**, a passenger cabin **1304**, wheels **1306**, a front portion **1308**, and a windshield **1310**. The vehicle **1300** also includes an instrument panel **1312**.

The instrument panel **1312** has a top surface that is positioned adjacent to the windshield **1310** at a location that is upward relative to a lower edge of the windshield **1310**. As an example, the top surface of the instrument panel **1312** may be located at a distance above the lower edge of the windshield **1310** that is equal to between 10 percent and 30 percent of the height of the windshield **1310** (as measured along the windshield from the lower edge to an upper edge). Thus, the position of the instrument panel **1312** relative to the windshield **1310** shortens the daylight view section of the windshield **1310**.

The instrument panel **1312**, in this implementation, is formed in part from a compressible structure that, during an impact, is engaged and compressed by the windshield **1310** in order to resist intrusion. However, the instrument panel **1312** does not provide substantial support for the windshield **1310** in an intrusion direction (i.e., toward the passenger cabin **1304**). As an example, at least part of the instrument panel **1312** may be formed from a soft foam material.

FIGS. 14A-14B show a vehicle **1400** that includes components that are analogous to those of the vehicle **100**, including a vehicle body **1402**, a passenger cabin **1404**, wheels **1406**, a front portion **1408**, and a windshield **1410**. The vehicle **1400** also includes an instrument panel **1412**.

The instrument panel **1412** is similar to the instrument panel **1312** and is configured per the previous description except as otherwise described. Thus, the instrument panel **1412** is positioned relative to the windshield **1410** to shorten the daylight view section of the windshield **1410** and is formed in part from a compressible structure that, during an impact, is engaged and compressed by the windshield **1410** in order to resist intrusion but does not provide substantial support for the windshield **1410** in the intrusion direction.

An inflatable structure **1440** is disposed inside the instrument panel **1412**, adjacent or within compressible portions of the instrument panel **1412**. The inflatable structure **1440** is initially in a deflated condition (FIG. 14A). In response to a detected impact or an imminent impact, the inflatable structure **1440** can be inflated (e.g., by a pyrotechnic inflator as with airbags) to define an inflated condition (FIG. 14B) in which the inflatable structure **1440** stiffens the instrument panel **1412**. A controller (e.g., computing device provided with executable program instructions) can determine whether to inflate the inflatable structure **1440** when the detected impact or imminent impact occurs, for example, based on sensor information that describes the impact, such as a direction or intensity. Thus, in some situations, the

inflatable structure **1440** is not inflated and the instrument panel **1412** remains compressible. In other situations, the inflatable structure **1440** is inflated and reduces the compressibility of the instrument panel **1412**.

FIG. **15** shows a windshield assembly **1511** that can be used with the vehicle **100** or other vehicles. The windshield assembly **1511** includes a windshield **1510** that can be similar to the windshield **110** and installed in a vehicle in the same manner. The windshield assembly **1511** also includes a film layer **1560** that is adhered to the interior surface of the windshield **1510** on the side of the windshield **1510** that faces a passenger cabin of the vehicle. Thus, the film layer **1560** is exposed to the passenger cabin of the vehicle, as opposed to being disposed between two layers of glass or plastic as part of a laminated structure. The film layer **1560** can be a thin, transparent cover sheet on the inside of the windshield **1510** to prevent intrusion of loose particles. As an example, the film layer **1560** may be formed from polyvinyl butyral (PVB).

FIGS. **16A-16B** show a windshield assembly **1611** that can be used with the vehicle **100** or other vehicles. The windshield assembly **1611** can be configured as described with respect to the windshield assembly **1511** except as noted, including a windshield **1610** and a film layer **1660** formed from, for example, PVB. A translucent inflatable structure **1662** is located between the windshield **1610** and the film layer **1660** and an inflator **1664** is configured to supply inflation gas to the translucent inflatable structure **1662**. As an example, the inflator **1664** can be a pyrotechnic inflator, as with airbags. The translucent inflatable structure **1662** is initially in a deflated condition (FIG. **16A**). In response to a detected impact or an imminent impact, the translucent inflatable structure **1662** can be inflated by the inflator **1664**. This creates an inflated volume in contact with the windshield **1610** to restrain intrusion of loose particles. In addition, the film layer **1660** is separated from the windshield **1610**, such that cracking of the windshield **1610** does not cause corresponding tearing of the film layer **1660**.

In some implementations, a separate inflatable structure is omitted. Instead, the film layer **1660** is located adjacent to the windshield **1610**, but is not bonded to it, and the space between the windshield **1610** and the film layer **1660** is inflatable to separate the film layer **1660** from the windshield **1610**.

FIG. **17** is a block diagram that shows an intrusion control system **1780** that includes active components that are actuated in response to a sensed impact or an imminent impact in order to prevent intrusion of objects into the passenger cabin of a vehicle through the windshield area. The intrusion control system **1780** includes a controller **1781**, sensors **1782**, and an intrusion control device **1783**. The controller **1781** is a device that is operable to determine whether to activate the intrusion control device **1783** in response to inputs, such as information received from the sensors **1782**. The controller **1781** may be, for example, a computing device provided with program instructions. The program instructions can cause the controller **1781** to activate the intrusion control device **1783** in response to a sensed impact or an imminent impact. As an example, the sensors **1783** may include contact sensors or accelerometers, and the outputs of these can be used to detect an impact, such as when the contact sensors indicate contact or when the accelerometers indicate an acceleration or differential acceleration (from two sensors) in excess of a threshold. An imminent impact can be determined, for example, by using the sensors **1783** to track objects, predicting likely future positions of the objects, and identifying an imminent impact

based on the predicted future positions. The intrusion control devices **1783** is any type of controllable device that can be deployed to restrain entry of objects through the windshield area of a vehicle, such as the devices described in connection with FIGS. **2-16B**.

What is claimed is:

1. An apparatus for resisting entry of objects through a windshield of a vehicle that has a passenger cabin, the apparatus comprising:

an instrument panel that is located between a lower edge of the windshield and the passenger cabin;
an airbag that is spaced from the windshield and deployable from an interior surface of a roof into an area above the instrument panel to resist entry of objects through the windshield into the passenger cabin; and
a reaction surface that is formed from a surface of the instrument panel,

wherein the reaction surface is configured to move from a lowered position generally contiguous with a remainder of the surface of the instrument panel to a raised position generally perpendicular to the remainder of the surface, and

wherein the reaction surface is configured to engage with an end portion of the airbag to resist movement of the airbag into the passenger cabin in a longitudinal direction in the raised position.

2. The apparatus of claim 1, wherein the airbag extends across at least ninety percent of an interior dimension of the vehicle in a lateral direction.

3. The apparatus of claim 1, wherein the airbag occupies a majority of a height between the instrument panel and the roof to separate the windshield from the passenger cabin.

4. The apparatus of claim 1, wherein the reaction surface is configured to rotate from the lowered position to the raised position upon deployment of the airbag for engagement with the airbag.

5. The apparatus of claim 4, wherein the reaction surface rotates in response to translation of a front portion of the remainder of the surface of the instrument panel in a generally longitudinal direction toward the passenger cabin.

6. The apparatus of claim 4, wherein the reaction surface pivots with respect to the remainder of the surface of the instrument panel at a joint, and wherein the joint includes a living hinge or a pin.

7. The apparatus of claim 4, wherein the reaction surface, in the raised position, occupies a majority of a height between the instrument panel and the roof to separate the windshield from the passenger cabin.

8. The apparatus of claim 1, wherein the reaction surface is moved by at least one of a mechanical actuator or a pyrotechnic actuator.

9. A method for resisting entry of objects through a windshield of a vehicle that has a roof, an instrument panel, and a passenger cabin, the method comprising:

detecting an impact or an imminent impact; and

based on detecting the impact or the imminent impact:

deploying an airbag that is spaced from the windshield from an interior surface of the roof into an area above the instrument panel to resist entry of objects through the windshield into the passenger cabin; and

deploying a reaction surface from the instrument panel, the reaction surface configured to rotate from a lowered position generally flush with a surface of the instrument panel to a raised position extending upward from the surface of the instrument panel toward the roof, and the reaction surface configured to engage with an end portion of the airbag in the

11

raised position to resist movement of the airbag into the passenger cabin in a longitudinal direction, wherein the instrument panel is located between a lower edge of the windshield and the passenger cabin.

10. The method of claim 9, wherein the reaction surface is formed on a moveable portion of the instrument panel that moves upon deployment of the airbag for engagement with the airbag.

11. The method of claim 10, wherein the moveable portion of the instrument panel rotates in response to translation of a front portion of the instrument panel in a generally longitudinal direction during the impact.

12. The method of claim 10, wherein the moveable portion pivots with respect to a remainder of the instrument panel at a joint, and wherein the joint includes a living hinge or a pin.

13. The method of claim 10, wherein the moveable portion is moved by at least one of a mechanical actuator or a pyrotechnic actuator.

14. The method of claim 10, wherein the moveable portion, when deployed, occupies a majority of a height between the instrument panel and the roof to separate the windshield from the passenger cabin.

15. The method of claim 9, wherein when deployed, the airbag extends across at least ninety percent of an interior dimension of the vehicle in a lateral direction.

16. An apparatus for resisting entry of objects through a windshield of a vehicle that has a passenger cabin, the apparatus comprising:

12

an instrument panel that is located between a lower edge of the windshield and the passenger cabin;
an airbag that is deployable from an interior surface of a roof into an area above the instrument panel to resist entry of objects through the windshield into the passenger cabin; and

a reaction surface configured to:

rotate from a lowered position generally flush with a surface of the instrument panel to a raised position extending upward from the surface of the instrument panel toward the roof; and

engage with an end portion of the airbag in the raised position to resist movement of the airbag into the passenger cabin.

17. The apparatus of claim 16, wherein the reaction surface is configured to rotate from the lowered position to the raised position upon deployment of the airbag for engagement with the end portion of the airbag.

18. The apparatus of claim 16, wherein the reaction surface rotates in response to translation of a front portion of the instrument panel toward the passenger cabin during an impact.

19. The apparatus of claim 18, wherein the reaction surface pivots with respect to a remainder of the surface of the instrument panel at a joint, and wherein the joint includes a living hinge or a pin.

20. The apparatus of claim 16, wherein the reaction surface is rotated by at least one of a mechanical actuator or a pyrotechnic actuator.

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